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Design of 250 W AC Series Motor

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Abstract

Objectives: This article is aimed at providing a detailed design of a 250 W AC series motor. Analytical design of the motor is performed to determine the armature winding design, commutator diameter, magnetic circuit analysis. The motor is simulated to estimate its performance. **Methods/Statistical Analysis:** To estimate the performance of the motor, the motor is simulated and finite element analysis is implemented to determine the flux density, electromagnetic torque under different operating speeds. The results of magnetic circuit design and commutator design are used in the finite element method to simulate the motor accurate to practical conditions. Form the obtained results the losses are determined. **Findings:** The results obtained include the flux density plot and the electromagnetic torque for different speeds. From the obtained results the performance of the motor is evaluated and the losses are tabulated. **Applications/Improvements:** The motor is designed to run a washing machine. Other general applications of the motor are mixers, drilling machines, vacuum cleaners, water sprinklers.

Keywords: AC Series Motor, Commentator, Finite Element Analysis, Magnetic Circuit, Silicon Steel

1. Introduction

The universal motor is widely used due to its power rating in the range of fractional kilowatts, very high speeds in the range of 20 rpm to 20000 rpm which is not provided by any conventional motors. The advantage of its availability in small sizes makes it useful in the field of agriculture; other major applications of this motor are washing machines, vacuum cleaners, drilling machines, mixers etc. Many design structures have been incorporated for the ac series motor to improve its performance for meeting the consumer requirements. One such design is the use of soft magnetic composites. The motor being useful in many day to day domestic applications requires refining its performance and its design[1-4].The analytical design of the motor is performed in which the commutator design is dealt in detail.

2. Analytical Design

2.1 Armature Winding Design

The armature and stator are built of silicon steel with the armature having 18 slots. As the machine is a two pole machine, we use double layer progressive lap winding wound around the armature. Since we use double layer winding, the number of commutator segments is equal to the number of coils which is 18 for which the back pitch is taken to be 19 and the front pitch as 17.

Let C – the number of coils on the armature periphery.

p - The number of poles.

2.2 Magnetic Circuit Design

Magnetic circuit analysis is performed in order to determine the distribution of magnetic flux density at different parts of the machine and to calculate the necessary ampere turns (mmf) required to establish the same all across the machine. The total mmf fed to the machine is split into five parts each for the stator back iron, stator tooth, rotor back iron, rotor tooth and the air gap. The output power of the motor and the main dimensions are related as,

$$P = \pi^2 B_{av}(ac)D^2LN \text{ kW} \quad (1)$$

Where,

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N- Speed of the motor in rps,
P- Output power,
D- bore diameter,
B_{av} - specific magnetic loading,
ac - specific electric loading,
L – Stack length.

The specifications of the motor are given in Table 1.

Table 1. Motor specifications

Parameters	Proposed model
Voltage	230V
Speed	14000rpm
Output power	250W
Efficiency	68.88%

The air gap flux is determined from specific magnetic loading as,

$$\phi = B_{av} D\, L \quad \text{Wb} \tag{2}$$

From the value of air gap flux the flux densities at different parts of the machine such as air gap, stator back iron, stator tooth, rotor back iron, rotor tooth are determined for which the necessary ampere turns are tabulated in Table 2.

Table 2. Magnetic circuit analysis

Machine parts	Ampere turns(A/m)
Air gap	332.904
Stator back iron	3779.597
Stator tooth	96.289
Rotor back iron	70.3268
Rotor tooth	510.340

2.3 Commutator Design

The diameter of the commutator is limited by the peripheral velocity given as

$$\pi D_c N \le 15\, m/s \tag{3}$$

The diameter of the commutator is chosen to be half of the bore diameter and the brush width equal to the width of the commutator segment. The dimensions of the brush are computed in proportion to the width of commutator bars accordingly the brush angle is determined. The designed values of the commutator and brushes are tabulated in Table 3.

$$D_c = 0.5\, D \quad \text{mm} \tag{4}$$

Segment thickness

$$t = \pi D_c / 18 \quad \text{mm} \tag{5}$$

Commutator bar thickness

$$d = t - 0.4 \quad \text{mm} \tag{6}$$

$$\text{Area of brush} = I / \delta;\ mm^2 \tag{7}$$

δ - Current density of the brush material. Generally taken to be 10 A/cm^2,

I – rated current at the brush.

Brush width b = d = t-0.4mm (8)

Table 3. Commutator parameters

Parameters	Calculated values
Diameter of Commutator	25 mm
Segment thickness	4.36 mm
Commutator bar thickness	4.03 mm
Brush Area	0.258 cm2
Brush Width	4.36 mm
Brush Height	8.7 mm

3. Finite element analysis

To optimize and predict the performance of the motor Finite Element Analysis (FEA) is adopted. The numerical technique is used to compute the developed torque, current drawn by the machine and the magnetic flux density distribution. The finite element model of the motor is shown in Figure 1. The transient 2-D analysis is performed on the motor for different speeds to compute the electromagnetic torque. To simulate the actual motor, the commutator and brushes were designed in the software and motion analysis was performed to evaluate the performance of the motor under transient conditions.

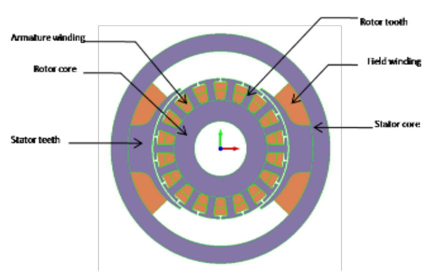

Figure 1. Finite element model of the motor.

4. Results

The results of 2–D Transient motion analysis are depicted and described in this section. All the results show the variation of rotor current and the electromagnetic torque with time. The model is simulated for a minimum of 3 cycles and the starting performance of the motor at different speeds are Shown. The flux density plot shows the distribution of magnetic flux density with a maximum flux density of 2.5 Tesla which is shown in Figure 2. The results of source current and torque at 14000 rpm are shown in Figure 3 and Figure 4. They show a peak current of 1 A when run at rated rpm. Form these results the losses are computed and it is compared with the existing model. The total copper loss of the designed model is computed through FEA as 19.418 W and the iron losses summing to 2.1415 W. The total losses together being 21.559 W.

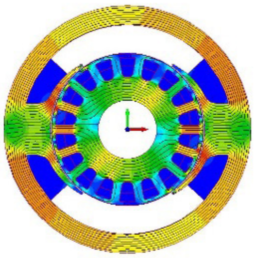

Figure 2. FEA flux density plot - showing different values of flux density at different parts. The maximum flux density is shown by the dark red portion.

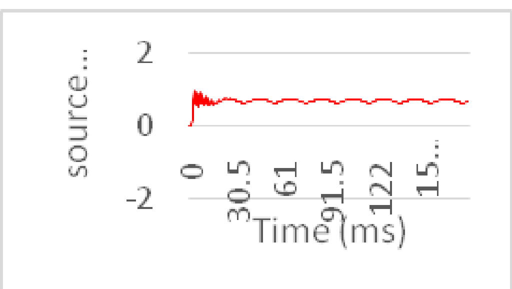

Figure 3. FEA result-source current at 14000 rpm.

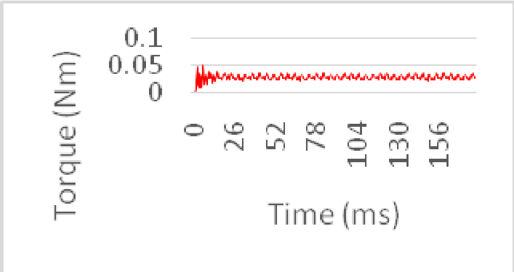

Figure 4. FEA result-torque at 14000 rpm.

5. Conclusion

A Universal motor rated for 250 W was designed to function under the operating conditions provided by a washing machine. The designed motor provides an efficiency of 68.88%. Further by providing certain design modifications in the shape of the stator structure we will be able to obtain better performance with improved efficiency.

6. References

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